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(54) **VARIABLE FLOW VALVE HAVING  
METERED FLOW ORIFICE**

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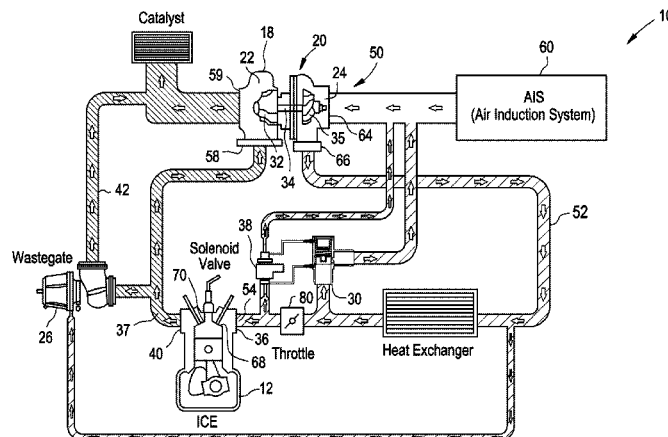
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(57) **ABSTRACT**

A variable flow valve assembly is disclosed, and includes a main body and a piston. The main body defines a chamber, an inlet port, an outlet port, and a wall located between the inlet port and the outlet port. The wall defines a metering orifice for selectively allowing a medium to flow from the inlet port to the outlet port. The piston is moveable within the chamber of the main body in a plurality of partially open positions to vary the amount of medium flowing through the modulation orifice.

**4 Claims, 6 Drawing Sheets**



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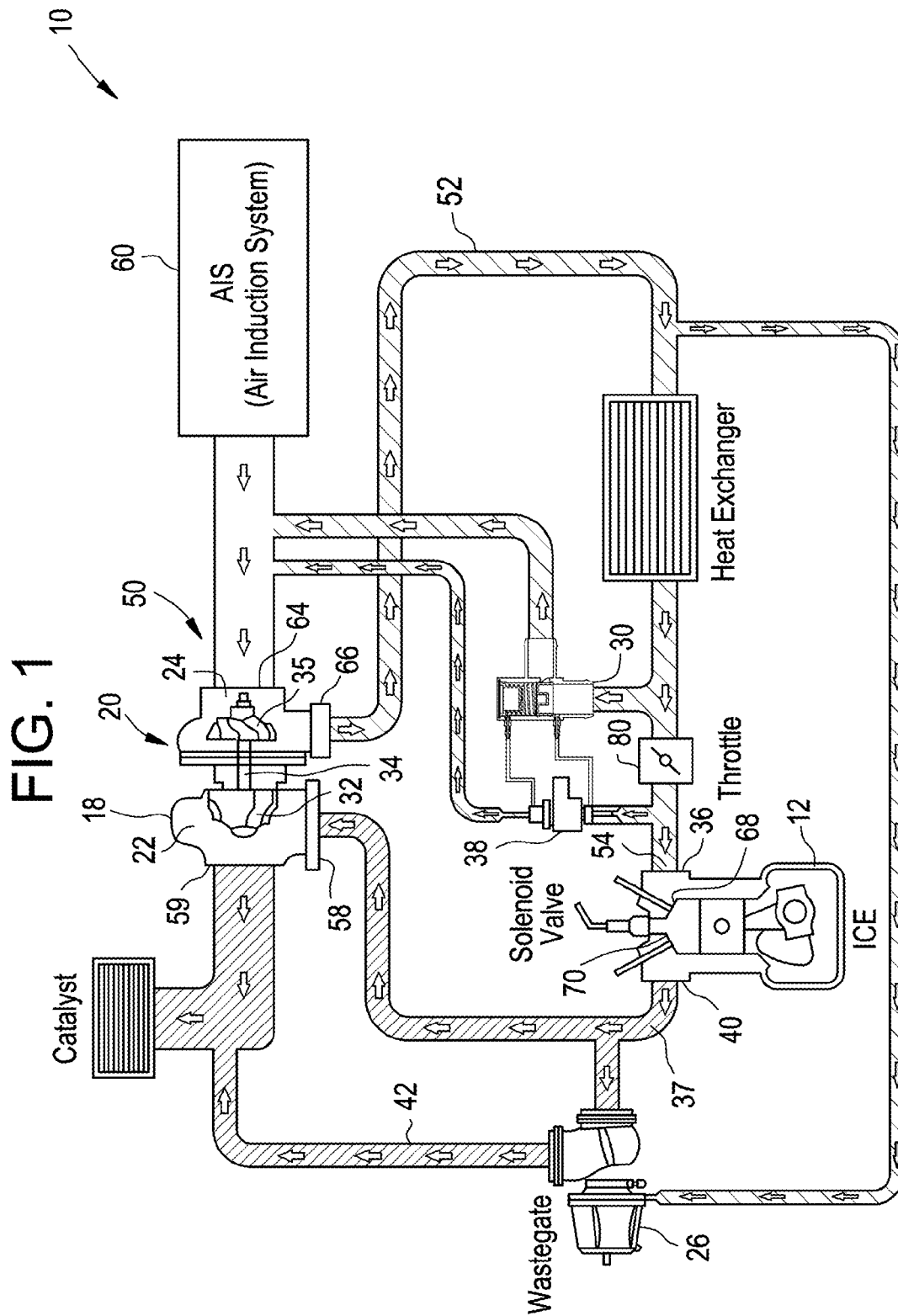


FIG. 2

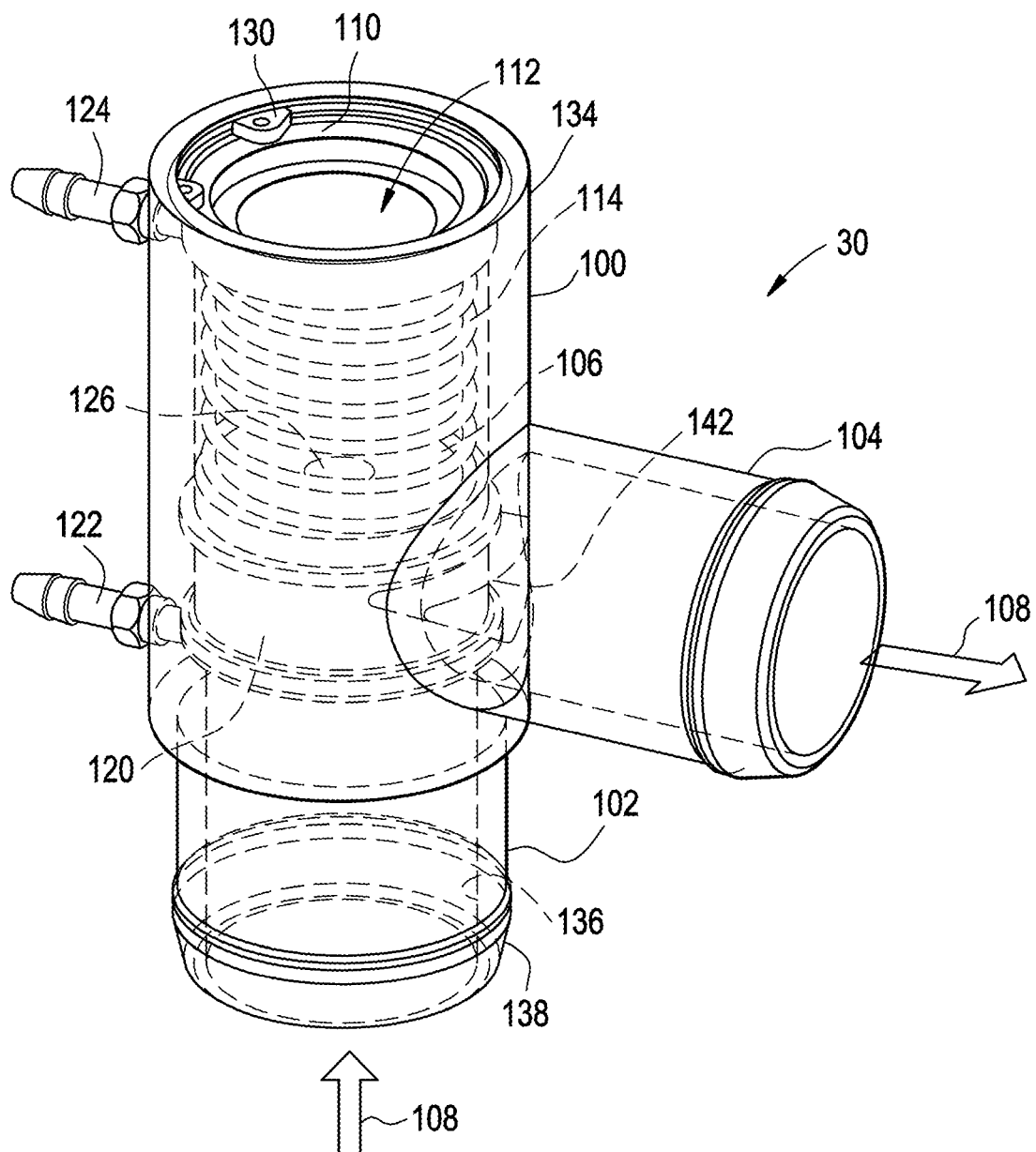






FIG. 5

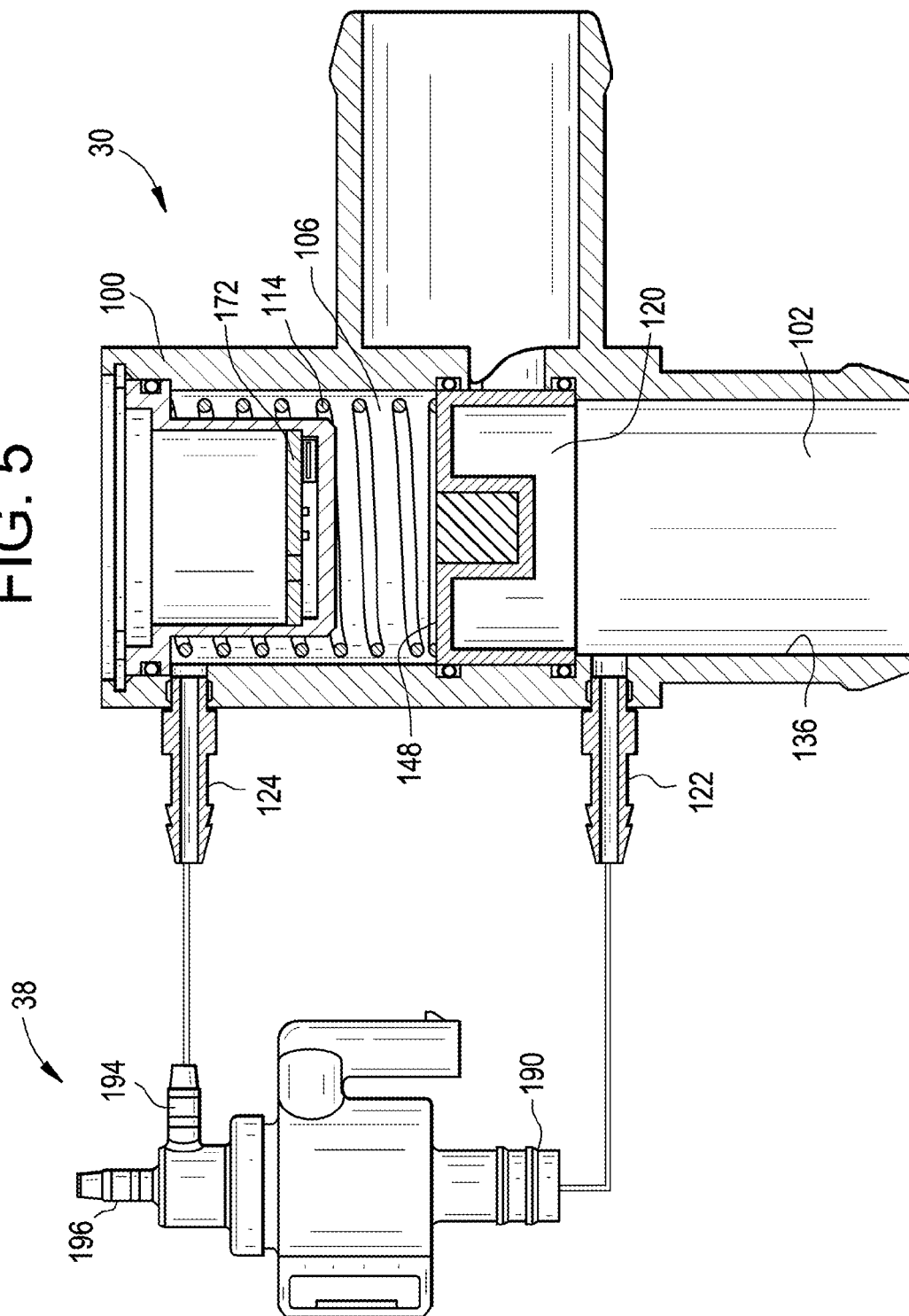
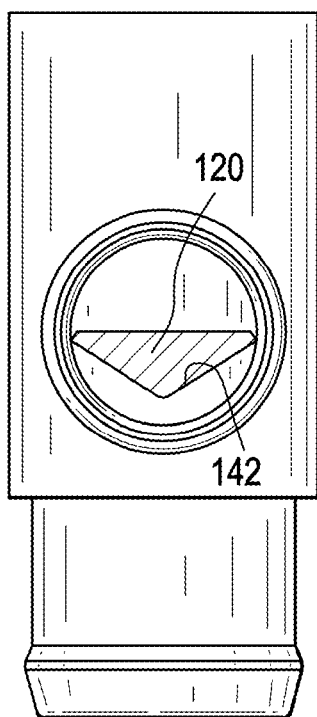
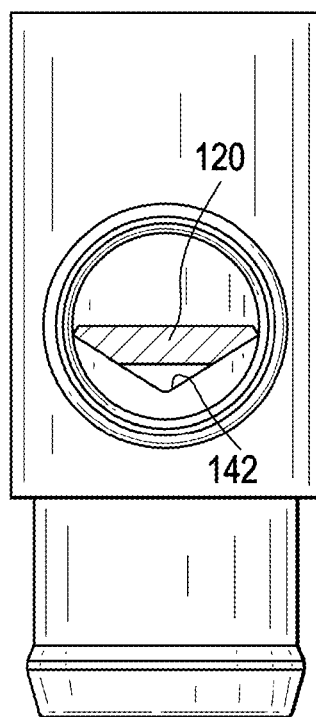


FIG. 6A



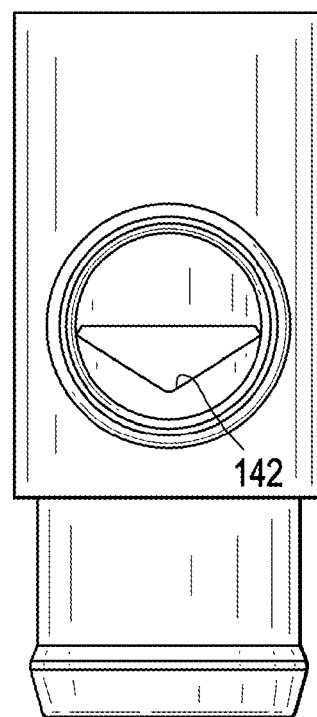
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FIG. 6B



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FIG. 6C



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# VARIABLE FLOW VALVE HAVING METERED FLOW ORIFICE

## TECHNICAL FIELD

The present invention relates generally to a variable flow valve, where the valve includes a metering orifice for modulating the amount of flow.

## BACKGROUND

Internal combustion engines may be used in a variety of applications such as, for example, passenger and industrial vehicles, marine, stationary and aerospace applications. There are generally two dominant ignition cycles, which are commonly referred to as gas and diesel cycles, or more formally as spark ignited (SI) and compression ignition (CI) cycles, respectively.

Exhaust-driven turbochargers may be used to improve the power output and overall efficiency of an internal combustion engine. Specifically, exhaust gas energy may be used to drive a turbine. The turbocharger includes a compressor and a turbine, where the compressor is mounted on a shaft of the turbocharger, opposite the turbine. The turbine converts engine exhaust gas into mechanical energy, which is used to drive the compressor. The compressor draws in and compresses air. The compressed air is then directed to an intake manifold of the internal combustion engine.

A relief valve, such as a compressor discharge valve or a blow-off valve, may be mounted on an intake pipe located downstream of the turbocharger before a throttle. Specifically, a compressor discharge valve may be used to vent compressed air back into an inlet of the compressor. A blow-off valve is similar to a compressor recirculation valve, but vents to the atmosphere rather than back to the inlet of the compressor. The relief valve may be used to alleviate a sudden surge or spike in pressure that may occur when the throttle closes (i.e., when an operator suddenly lifts his or her foot off of the gas pedal and the throttle closes). Some types of relief valves currently available may only be completely opened or shut. In other words, some relief valves do not provide active control of the position of the valve.

## SUMMARY

The disclosed variable flow valve assembly includes a modulation orifice that varies the amount of medium, such as air or fluid, that flows through the relief valve. Specifically, in one aspect, a variable flow valve assembly is disclosed, and includes a main body and a piston. The main body defines a chamber, an inlet port, an outlet port, and a wall located between the inlet port and the outlet port. The wall defines a metering orifice for selectively allowing a medium to flow from the inlet port to the outlet port. The piston is moveable within the chamber of the main body in a plurality of partially open positions to vary the amount of medium flowing through the modulation orifice.

In one aspect, the disclosed variable flow valve assembly may include a position sensor, a controller, and a solenoid. The position sensor determines the position of the piston within the chamber of the main body. The controller is in signal communication with the position sensor and the solenoid. The chamber of the main body of the variable flow valve includes a pressurized chamber. The piston separates the pressurized chamber from the inlet port. The solenoid applies a predetermined amount of vacuum to the pressurized cham-

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ber. The predetermined amount of vacuum causes the piston to move into one of the plurality of open positions.

In another aspect, a system for controlling an exhaust driven turbocharging system is disclosed. The system includes a turbocharger having a compressor inlet in fluid communication with a variable flow valve assembly and an intake manifold of an engine. The variable flow valve assembly includes a main body, a piston, a position sensor, and a controller. The main body defines a chamber, an inlet port, an outlet port, and a wall located between the inlet port and the outlet port. The wall defines a metering orifice for selectively allowing a medium to flow from the inlet port to the outlet port. The piston is moveable within the chamber of the main body in a plurality of partially open positions to vary the amount of medium flowing through the modulation orifice. The position sensor determines the position of the piston within the chamber of the main body. The controller is in signal communication with the position sensor. The position of the piston within the chamber is determined by the controller. The metering orifice is partially opened in order to communicate air into the intake manifold of the engine.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram including flow paths and flow directions of one embodiment of an internal combustion engine turbo system that includes a relief valve.

FIG. 2 is a perspective, partially transparent view of one embodiment of the relief valve in a closed position.

FIG. 3 is a cross-sectional view of the relief valve of FIG. 2 in the closed position.

FIG. 4 is a cross-sectional view of the relief valve of FIG. 2 in an open position.

FIG. 5 is a cross-sectional view of the relief valve of FIG. 2 fluidly connected to a solenoid in the closed position.

FIG. 6A is a front view of the relief valve in the closed position.

FIG. 6B is a front view of the relief valve in a partially open position.

FIG. 6C is a front view of the relief valve in the open position.

## DETAILED DESCRIPTION

The following detailed description will illustrate the general principles of the invention, examples of which are additionally illustrated in the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements.

Referring now to FIG. 1, an exemplary schematic diagram of a turbo system 10 for an internal combustion engine 12 is illustrated. The turbo system 10 may include an exhaust-driven turbo charger ("EDT") 20 having a turbine section 22 and compressor section 24, a turbine bypass valve or wastegate 26, and a relief valve 30. An exhaust housing 18 of the EDT 20 contains a turbine wheel 32. A turbine wheel 32 harnesses and converts exhaust energy into mechanical work through a common shaft 34 to turn a compressor wheel 35. The compressor wheel 35 ingests, compresses and feeds air at elevated operating pressures into an intake manifold 36 of the internal combustion engine 12.

The wastegate 26 is a control valve used to meter an exhaust volume 37 exiting an exhaust manifold 40 of the internal combustion engine 12, and controls the amount of energy available to power the turbine wheel 32. The wastegate 26 works by opening a valve (not shown) connected to a bypass pipe 42. Opening the valve of the wastegate 26 allows

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for exhaust to flow away from the turbine wheel **32**. Thus, the wastegate **26** may have direct control over the speed of the EDT **20** and the resultant operating pressure of the intake manifold **36** of the internal combustion engine **12**. The wastegate **26** may have any number of embodiments, including the

embodiments disclosed in applicants' U.S. Pat. No. 8,469, 333, which is incorporated by reference herein in its entirety. Operating pressures exist in an EDT compressor inlet **50**, the intake manifold **36** of the internal combustion engine **12** and an intake manifold pipe **52**, the exhaust manifold **40** of the internal combustion engine **12** and an intake manifold pipe **54**, an exhaust inlet **58** of the EDT **20**, and an exhaust outlet **59** of the EDT **20**. Specifically, the EDT compressor inlet **50** may be defined as the passageway from an air intake system **60** to an inlet **64** of the compressor section **24**. The intake manifold **36** of the internal combustion engine **12** may be defined as the passage between an EDT compressor discharge **66** and one or more intake valves **68** of the internal combustion engine **12**. The exhaust manifold **40** of the internal combustion engine **12** may be defined as the passage between one or more exhaust valves **70** and the exhaust inlet **58** of the EDT. The exhaust may be any passageway located after the exhaust outlet **59** of the EDT **20**. In order to achieve effective exhaust gas recirculation (EGR), the pressures in an exhaust manifold should be significantly higher than the pressures found in an intake manifold in order for exhaust gas to flow in the correct direction. Smaller EDT exhaust profiles produce higher desired exhaust manifold pressures, but at the expense of lower efficiencies. Thus, those skilled in the art will appreciate that a fine balance exists between achieving efficiency of the internal combustion engine **12** and EGR effectiveness.

The relief valve **30** may be a regulating valve located in the intake manifold pipe **52** between the compressor discharge **66** of the compressor section **24** of the EDT **20** and the intake manifold **36** of the internal combustion engine **12**. In the embodiment as shown in FIG. 1, the relief valve **30** is a compressor recirculation valve that is fluidly connected to and vents compressed air back into the EDT compressor inlet **50**. However, it should be noted that in another embodiment, the turbo system **10** may utilize a blow-off valve as well. A blow-off valve is similar to a compressor recirculation valve, but vents to the atmosphere rather than back to the compressor inlet of an EDT. A solenoid **38** may be connected to the relief valve **30**. In one embodiment, the solenoid **38** may be used to apply vacuum to and actuate the relief valve **30**, which is described in greater detail below.

In the exemplary embodiment as shown in FIG. 1, the relief valve **30** may be used with a spark ignited internal combustion engine **12** and a throttle plate **80**. At any given operating range of the internal combustion engine **12**, the shaft **34** of the EDT **20** may be spinning up to 200,000 revolutions per minute (RPM). A sudden closing of the throttle **80** does not immediately decelerate the RPM of the EDT **20**. Therefore, this closing creates a sudden increase in pressure in the passages between the closed throttle **80** and EDT compressor section **24** (e.g., the intake manifold pipe **52**). The relief valve **30** may be used to relieve or bypass the pressure created by the sudden closing of the throttle **80**.

When the relief valve **30** is opened the EDT **20** may spin freely, thereby conserving the inertia of the EDT **20**. If the relief valve **30** was omitted, the EDT **20** would stall or stop once the throttle **80** is closed. This stalling or stopping may adversely affect EDT life and throttle response. Those skilled in the art will appreciate that the EDT **20** should be spinning and ready to produce boost as soon as the throttle plate **80** is opened. The relief valve **30** may decrease turbo lag by allowing the EDT **20** to spin up to speed (i.e., spool up) without

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compressor load, as there is no back pressure present once the relief valve **30** is opened. A variable relief valve, which is described in greater detail below, may be especially beneficial by allowing just the amount of bypass to be ready for immediate boost to substantially prevent compressor surge. Compressor surge may be defined as when the air pressure after the compressor wheel **35** is actually higher than what the compressor wheel **35** is capable of maintaining. This condition causes the airflow in the compressor wheel **35** to back up, build pressure, or stall. Thus, compressor surge is noisy, affects EDT life, and may reduce the performance of the turbo system **10**.

The relief valve **30** may be employed in any EDT enabled internal combustion engine, including a diesel engine. Although a turbo system **10** is disclosed, those skilled in the art will readily appreciate that the relief valve **30** may be used in any application where the flow of a medium such as fluid or gas may be modulated or varied. In other words, the relief valve **30** may include a plurality of partially opened positions to vary the amount of exhaust gas to the intake manifold **36** of the internal combustion engine **12** (FIG. 1).

Referring to FIGS. 2-3, the relief valve **30** may include a valve body **100** that defines an inlet port **102**, an outlet port **104**, and a pressurized chamber **106**. In the exemplary embodiment as shown in FIGS. 2-3, the lower port is the inlet port **102**, and the port located on the right hand side of the valve body **100** is the outlet port **106**. However, it is to be understood that the direction of flow **108** may be reversed, and the port **102** may be used as an outlet port, and the port **104** may be used as an inlet port. The valve **30** may also include a snap ring **110**, a cover **112**, a biasing element **114**, a piston **120**, a vent fitting **122**, a vent fitting **124**, and a magnet **126**. The snap ring **110** may define one or more eyelets **130** (FIG. 2). The snap ring **110** may be seated within an annular recess **132** located at a first end **134** of the valve body **100**.

In the exemplary embodiment as shown in FIGS. 2-3, the valve body **100** may define a generally cylindrical chamber **136** extending between the first end **134** and a second end **138**. The piston **120** may be sized to translate in a linear direction within the chamber **136** of the valve body **100**. The piston **120** may also separate the inlet port **102** from the pressurized chamber **106**. FIGS. 2-3 illustrate the valve **30** in a closed position, and FIGS. 4 and 6C illustrate the valve **30** in an open position. Specifically, the piston **120** may translate or move up and down incrementally within the cylindrical chamber **136** of the valve body **100**. As best seen in FIG. 3, a metering or modulation orifice **142** may be defined by a generally cylindrical wall **140** that defines a portion of the chamber **136**. The wall **140** may include a first side **144** and a second side **146**. The first side **144** of the wall **140** may define a portion of the outlet port **104**, and the second side **146** of the wall **140** may define a portion of the chamber **136**.

The modulation orifice **142** may be used to selectively allow for a medium, such as fluid or gas, to flow from the inlet port **102** to the outlet port **104**. The modulation orifice **142** may also be used to vary or modulate the amount of medium that passes from the inlet port **102** to the outlet port **104**. Specifically, when the valve **30** is in the closed position (FIGS. 2-3 and 6A), the piston **120** may generally block or prevent a medium from flowing from the inlet port **102** to the outlet port **104**. The piston **120** may be actuated into a plurality of partially opened positions (one of which is shown in FIG. 6B) in response to signals generated by a position sensor **150**, which is described in greater detail below. The piston **120** is moveable within the chamber **136** of the valve **100** in a plurality of partially opened positions, which in turn varies the amount of medium that may flow through the modulation

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orifice 142. When the relief valve 30 is in the completely open position (FIG. 4), a medium may flow through the modulation orifice 142 without any substantial obstruction or blockage by the piston 120.

As best seen in FIGS. 3-4, the piston 120 may include an upper surface 148 and a lower surface 149. Two sealing members 168 and 169 may be seated within the cylindrical chamber 136 of the valve body 100. Specifically, if the relief valve 30 is in the closed position, the sealing member 168 may be aligned with and provide sealing between the pressurized chamber 106 of the valve body 100, the modulation orifice 142, and the piston 120. Likewise, the sealing member 169 may be aligned with and provide sealing between the inlet port 102 of the valve body 100, the modulation orifice 142, and the piston 120. The sealing members 168, 169 may be any type of seal for reciprocating components such as an O-ring.

In the exemplary embodiment as shown, the modulation orifice 142 includes a generally inverted triangular profile. Thus, as the piston 120 moves upwardly from the closed position (FIGS. 2-3) and into the open position (FIG. 4), the amount of flow passing through the modulation orifice 142 increases exponentially. In other words, as the lower surface 149 of the piston 120 is moved into the fully open position, the amount of flow through the modulation orifice 142 may increase at a faster rate. Although an inverted triangle is illustrated, those skilled in the art will readily appreciate that the modulation orifice 142 may take on a variety of different shapes and configurations in order to control the amount of flow. The shape of the modulation orifice 142 may depend upon a number of variables such as, but not limited to, noise (i.e., to control whistling through the valve 30) and the distance the piston 120 may travel within the cylindrical chamber 136 of the valve body 100. For example, in an alternative embodiment, the modulation orifice 142 may include a slot-

Referring to FIG. 3, the cover 112 may be located within the pressurized chamber 106 of the valve body 100. The cover 112 includes a body 152 having an open end 154 and a closed end 156. A lip or rim 158 may be located at the open end 154 of the body 152. The valve body 100 may define a shelf 160. The rim 158 of the cover 112 may be seated against the shelf 160 of the valve body 100. A sealing element 162 such as, for example, an O-ring may be interposed between a side surface 164 of the rim 158 and a side surface 166 of the valve body 100. The cover 112 provides sealing between the pressurized chamber 106 of the valve body 100 and the atmosphere.

The body 152 of the cover 112 also defines a recess 170. A controller 172 and the position sensor 150 may be located within the recess 170 of the cover 112, where the controller 172 is in signal communication with the position sensor 150. The controller 172 may refer to an application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, or other suitable components that provide the described functionality.

The position sensor 150 may be any device that permits position measurement. In one embodiment, position sensor 150 is a relative position sensor (a displacement sensor) based on movement of the piston 120 within the cylindrical chamber 136 of the valve body 100. The position sensor 150 may be a capacitive transducer, an eddy-current sensor, a grating sensor, a Hall-effect sensor, an inductive non-contact position sensors, a laser Doppler Vibrometer (optical), a linear variable differential transformer (LVDT), a multi-axis displacement transducer, a photodiode array, a piezo-electric trans-

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ducer (piezo-electric), a potentiometer, a proximity sensor (optical), a seismic displacement pick-up, a string potentiometer (also known as string pot., string encoder, cable position transducer), or a combination thereof.

In the embodiment illustrated, the position sensor 150 is a Hall effect sensor comprising a chip/Hall effect position sensor 174 that sensors the displacement of the magnet 126. The magnet 126 may be connected to the piston 120 for translation therewith. Specifically, the magnet 126 may be mounted to or placed within the piston 120. In FIGS. 3 and 4, the magnet 126 is housed within a bracket 178 formed by a piston body 180. The bracket 178 suspends the magnet 126 within the piston 120.

The chip/Hall effect position sensor 174 may be positioned within the valve body 100 in sufficient proximity to sense the movement of the magnet 126 located within the piston 120, and determine the specific position of the piston 120 within the chamber 136 of the valve body 100. In the embodiment as shown in FIGS. 3 and 4, the chip/Hall effect position sensor 174 is oriented horizontally in a position above the magnet 126 (i.e., axial relative to the magnet 126). In another embodiment, the chip/Hall effect position sensor 174 may be oriented vertically in a position radially outward away from the magnet 126.

The biasing element 114 may include a first end 180 and a second end 182. The first end 180 of the biasing element 114 may be seated against the rim 158 of the cover 112, and the second end 182 of the biasing element 114 may be seated against the upper surface 148 of the piston 120. The biasing element 114 may be used to exert an axial force against the upper surface 148 of the piston 120. In the non-limiting embodiment as shown, the biasing element 114 is a coil spring, however those skilled in the art will appreciate that any type of biasing element for exerting an axial force against the piston 120 may be used as well.

FIG. 5 is an illustration of the relief valve 30 and the solenoid 38. The solenoid 38 may be used to create a pressure differential within the relief valve 30, thereby causing the piston 120 to travel within the chamber 136 of the valve body 100. Although a solenoid is illustrated, those skilled in the art will appreciate that other devices may be used as well to create a pressure differential within the relief valve 30 such as, for example, a pump for moving fluid or gas in either a positive or a negative direction.

The controller 172 may be in signal communication with the solenoid 38 in order to turn on the solenoid 38 and to move an armature (not illustrated). Specifically, the controller 172 may control the solenoid 38 based on the current position of the piston 120 within the chamber 136. The movement of the armature of the solenoid 38 may create a pressure differential between the inlet port 102 and the pressurized chamber 106 of the valve body 100. The piston 120 may translate or move within the chamber 136 of the valve body 100 based on a pressure differential between the inlet port 102 and the pressurized chamber 106, which is described in greater detail below.

In the embodiment as shown in FIG. 5, the solenoid 38 may include a first vent port 190, a second vent port 194, and a vacuum port 196. The first vent port 190 of the solenoid 38 may be fluidly connected to the vent fitting 122 of the valve 30, and the second port 194 may be fluidly connected to the vent fitting 124 of the valve 30. In one embodiment, the first vent port 190 and the second port 194 may be fluidly connected to the relief valve 30 using a connection hose (not illustrated). FIG. 5 illustrates the valve 30 in the closed position, where the controller 172 may control the armature of the solenoid 38 (not illustrated) in order to open the first vent port

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190 and close the vacuum port 196 to communicate pressure between the first vent port 190 and the second vent port 194. Thus, the pressure of the inlet port 102 is about equal to or balanced with the pressurized chamber 106 of the valve body 100. The axial force exerted by the biasing element 114 5 against the upper surface 148 of the piston 120 retains the piston 120 in place in the closed position within the chamber 136 of the valve body 100.

The controller 172 may control the solenoid 38 in order to create a pressure differential between the inlet port 102 and the pressurized chamber 106 of the valve body 100. Specifically, the controller 172 may control the armature of the solenoid 38 (not illustrated) in order to close the first vent port 190 and apply vacuum to the second vent port 194. Thus, the pressure of the inlet port 102 is no longer equal to the pressure located within the pressurized chamber 106 of the valve body 100. As a result, the piston 120 overcomes the axial force exerted by the biasing element 114, and the piston 120 may translate in an upward direction, and into the open position seen in FIG. 4. In one embodiment, the amount of vacuum applied to the second vent port 194 may be varied in order to control the position of the piston 120 within the chamber 136 of the valve body 100. In other words, the piston 120 may be positioned in one of the partially opened positions based on a predetermined amount of vacuum applied to the second vent port 194. In an alternative embodiment, the position of the piston 120 may be controlled using pulse width modulation (PWM) control. Specifically, the solenoid 38 may be modulated off and on using PWM control in order to position the piston 120 in one of the partially opened positions within the chamber 136 of the valve body 100.

Referring generally to the figures, the disclosed relief valve 30 includes a modulation orifice, which is used to vary the amount of medium that flows through the relief valve. Thus, referring specifically to FIG. 1, the relief valve 30 enables the control of an operating pressure of the exhaust manifold 40 on command. In particular, by partially opening the disclosed valve 30, the operating pressures in the exhaust manifold 40 may be controlled. Some types of compressor recirculation valves and blow-off valves currently available only have a fully open or a fully closed position. In contrast, the disclosed valve 30 may be opened into a plurality of positions, thereby allowing control of the operating pressure in the exhaust manifold 40 on command. This in turn will allow for more precise control of turbo speed. Moreover, turbo response time and turbo lag may be reduced. Finally, the disclosed relief valve 30 may also improve fuel economy as well as drivability of a vehicle.

The embodiments of this invention shown in the drawings and described above are exemplary of numerous embodiments that may be made within the scope of the appended claims. It is contemplated that numerous other configurations of the tensioner may be created taking advantage of the disclosed approach. In short, it is the applicant's intention that the scope of the patent issuing herefrom will be limited only by the scope of the appended claims.

What is claimed is:

1. A variable flow valve assembly, comprising:

a main body defining a chamber and a shelf, an inlet port, an outlet port, and a wall located between the inlet port and the outlet port, the wall defining a metering orifice

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for selectively allowing a medium to flow from the inlet port to the outlet port, wherein the chamber of the main body includes a pressurized chamber;

a piston moveable within the chamber of the main body in a plurality of partially open positions to vary the amount of medium flowing through the modulation orifice, wherein the piston separates the pressurized chamber from the inlet port;

a position sensor for determining the position of the piston within the chamber of the main body;

a controller that is in signal communication with the position sensor;

a solenoid in signal communication with the controller; and

a cover seated against the shelf of the main body, the cover providing sealing between the pressurized chamber and the atmosphere.

2. The variable flow valve assembly of claim 1, further comprising a biasing element that includes a first end and a second end, wherein the first end of the biasing element is seated against the cover, and the second end of the biasing element is seated against an upper surface of the piston.

3. A system for controlling an exhaust driven turbocharging system, comprising:

a turbocharger having a compressor inlet in fluid communication with a variable flow valve assembly and an intake manifold of an engine, the variable flow valve assembly comprising:

a main body defining a chamber and a shelf, an inlet port, an outlet port, and a wall located between the inlet port and the outlet port, the wall defining a metering orifice for selectively allowing a medium to flow from the inlet port to the outlet port, wherein the chamber of the main body includes a pressurized chamber; and

a piston moveable within the chamber of the main body in a plurality of partially open positions to vary the amount of medium flowing through the modulation orifice, wherein the piston separates the pressurized chamber from the inlet port;

a position sensor for determining the position of the piston within the chamber of the main body;

a controller that is in signal communication with the position sensor, wherein the position of the piston within the chamber is determined by the controller, and wherein the metering orifice is partially opened in order to communicate air into the intake manifold of the engine;

a solenoid in signal communication with the controller, wherein the solenoid applies a predetermined amount of vacuum to the pressurized chamber, and wherein the predetermined amount of vacuum causes the piston to move into one of the plurality of open positions; and

a cover seated against the shelf of the main body, the cover providing sealing between the pressurized chamber and the atmosphere.

4. The system of claim 3, further comprising a biasing element that includes a first end and a second end, wherein the first end of the biasing element is seated against the cover, and the second end of the biasing element is seated against an upper surface of the piston.

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